

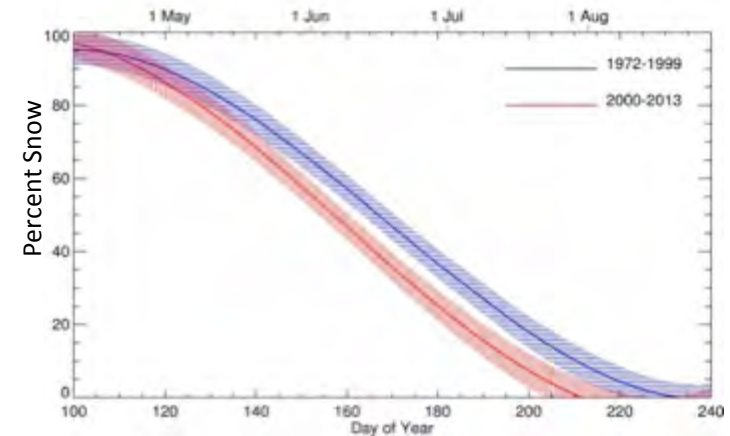


# Detection of earlier snowmelt in the Wind River Range, Wyoming, using the Landsat Image Archive, 1972-2013

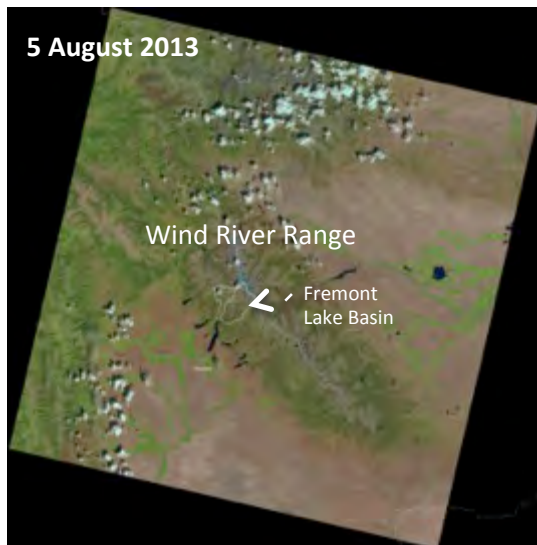
Dorothy K. Hall, Cryospheric Sciences Laboratory, NASA/GSFC

*Landsat-derived mean snow-cover depletion curves show that snow cover in the Fremont Lake basin of the Wind River Range, Wyoming, is melting  $16 \pm 10$  days earlier, on average, in the 2000s compared to the period from 1972 – 1999. Increasing spring and summer night-time air temperature and reduced stream discharge are the likely drivers of the earlier snowmelt documented in the Landsat record.*

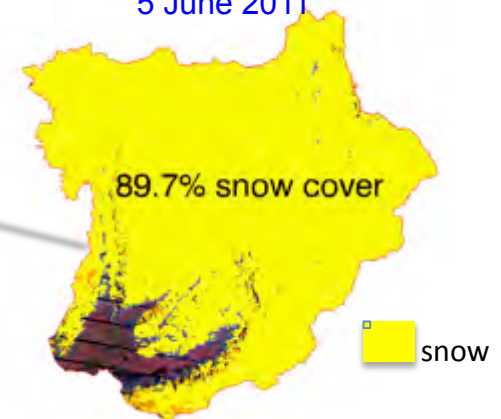
Snow-cover depletion curves in Fremont Lake Basin derived from Landsat images



Landsat Operational Land Imager (OLI) image showing the Wind River Range (left), and a zoom of the Fremont Lake Basin (right)



Example snow map of the Fremont Lake Basin derived from Landsat ETM+ data 5 June 2011





**Name:** Dorothy K. Hall, Cryospheric Sciences Lab, NASA/GSFC, Christopher J. Crawford, ORAU , Nicolo E. DiGirolamo, SSAI

**E-mail:** dorothe.k.hall@nasa.gov

**Phone:** 301-614-5771

## References:

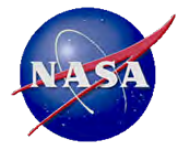
Hall, D.K., C.J. Crawford, N.E. DiGirolamo, G.A. Riggs and J.L. Foster, 2015: Detection of earlier snowmelt in the Wind River Range, Wyoming, using Landsat imagery, 1972-2013, *Remote Sensing of Environment* (in press).

**Hall, D.K.**, J.L. Foster, N.E. DiGirolamo and G.A. Riggs, 2012: Snow cover, snowmelt timing and stream power in the Wind River Range, Wyoming, *Geomorphology*, 137(1):87-93.

**Data Sources:** Landsat MSS, TM, ETM+ and OLI images from the U.S. Geological Survey (USGS) archive at the Earth Resources Observation and Science (EROS) Data Center [<http://glovis.usgs.gov/>]; MODIS Collection 6 (C6) daily snow-cover surface-reflectance-based maps at 500-m resolution; daily stream discharge data from the Pine Creek Above Fremont Lake gauge; daily temperature and daily precipitation records from the NOAA meteorological station at Pinedale; and daily SWE measurements from USDA SNOW TELemetry (SNOTEL) stations in the WRR.

**Technical Description of Figures:** Using Landsat images, snow cover was mapped in the Wind River Range (WRR) in northwestern Wyoming from 1972 – 2013. Consistent with the ongoing and severe drought, data from the Pine Creek Above Fremont Lake gauge show a striking reduction in cumulative stream discharge in the 2000s vs. the decades of the 1970s, 1980s and 1990s. Landsat-derived snow-cover depletion curves were generated for 1972 – 2013. MODerate-Resolution Imaging Spectroradiometer (MODIS)–derived standard snow-cover maps were also used to generate snow-cover depletion curves, from 2000 – 2013, to provide an accuracy assessment of the Landsat technique. Landsat-derived mean snow-cover depletion curves show that snow in the Fremont Lake basin is melting  $16 \pm 10$  days earlier, on average, in the 2000s compared to the period 1972 – 1999. Increasing spring and summer nighttime air temperature and lower stream discharge in the 2000s are the likely drivers of the trend toward earlier snowmelt.

**Scientific Significance:** In the western United States snow has been melting earlier in recent decades. This is particularly noticeable in the Pacific Northwest and other coastal areas, yet has been less obvious in locations farther inland. A reduction in stream discharge and a transition to earlier snowmelt have tremendous societal and economic impacts in Wyoming since streamflow is a significant contributor to the water resources of the state. In fact much of the streamflow in Wyoming originates from melting snow in the WRR, and is especially critical during the drought that is currently affecting the western states.



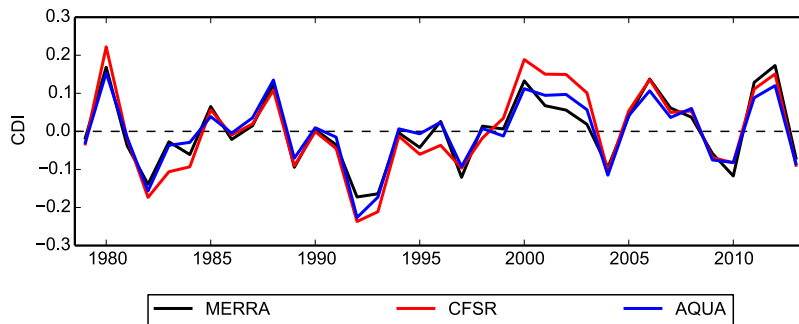
# Land-atmosphere coupling from satellite remote sensing as a drought-monitoring tool



Joshua K. Roundy<sup>1</sup> and Joseph A. Santanello, Jr.<sup>2</sup>

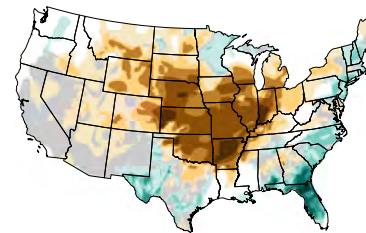
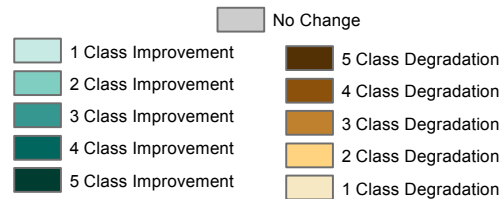
<sup>1</sup>Hydrological Sciences Laboratory, NASA/GSFC and ORAU; <sup>2</sup>Hydrological Sciences Laboratory, NASA/GSFC

## (1) Average US June-Aug CDI

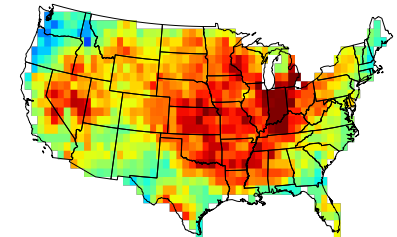
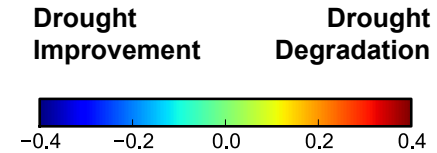


## (2) Change in the 2012 Drought (May 8 - July 31)

### US Drought Monitor



### AQUA CDI



NASA's AQUA satellite (AIRS and AMSR-E) provides the necessary variables to assess characteristics of drought from space by measuring the impact of land-atmosphere coupling through the Coupling Drought Index (CDI).



Name: Joshua K. Roundy, NASA/GSFC, Hydrological Sciences Lab  
E-mail: [joshua.roundy@nasa.gov](mailto:joshua.roundy@nasa.gov)  
Phone: 301-614-5319



#### References:

- Roundy, Joshua K., J. A. Santanello, 2015:** *Land-atmosphere coupling from satellite remote sensing as a drought-monitoring tool*, (in-preparation).
- Roundy, Joshua K. and E. F. Wood, 2015:** *The attribution of land-atmosphere interactions on the seasonal predictability of drought*. Journal of Hydrometeorology. doi:10.1175/JHM-D-14-0121.1.
- Roundy, J. K., C. R. Ferguson, & E. F. Wood, 2013:** *Temporal Variability of Land–Atmosphere Coupling and Its Implications for Drought over the Southeast United States*. Journal of Hydrometeorology, 14(2), 622–635. doi:10.1175/JHM-D-12-090.1.

#### Data Sources:

- AIRS** level 3 standard product which includes measurements of temperature, humidity and geopotential height at 12 pressure levels on a  $1^\circ \times 1^\circ$  grid from 2003-present. Only the nighttime (descending) overpass is used.
- AMSRE** level 3 product of soil moisture on a  $0.25^\circ \times 0.25^\circ$  grid from the Land Parameter Retrieval Model from 2003-2011. Again only the nighttime descending orbit is used.
- MERRA** and CFSR reanalysis using the atmospheric variables (temperature, humidity and geopotential height) and soil moisture.
- The US Drought monitor which combines a variety of drought indices to classify drought into 5 different levels of intensity. It is not expected that the CDI will be a perfect match to the USDM as the fundamental underpinnings are different, however it provides a baseline for which the general patterns of drought should be consistent.

#### Technical Description of Figures:

**Figure 1:** Intercomparison of the Coupling Drought Index (CDI; Roundy et al. 2013) anomalies from reanalysis (MERRA and CFSR) with remote sensing from the AQUA satellite (AIRS-AMSRE) for June-August over a 35 year period from 1979-2013. AQUA is only available from 2003 through present, therefore reanalysis is used to in-fill the shorter record and missing days. The remote sensing based estimates capture the year to year variation that are seen in the reanalysis.

**Figure 2:** The change in the spatial extent in drought classification between May 8, 2012 and July 31, 2012 for the US Drought Monitor and the spatial extent of the AQUA CDI anomalies for the same period. The AQUA CDI shows consistent spatial patterns of drought as compared to the US Drought Monitor which demonstrates the potential utility of the AQUA CDI as a global drought monitoring tool. Inconsistencies between the AQUA CDI and the US Drought Monitor can be attributed to the longer memory and specific drought classifications in the US Drought Monitor.

**Scientific significance, societal relevance, and relationships to future missions:** The AQUA CDI has particular application in drought monitoring and can be utilized in conjunction with the Coupling Statistical Model (Roundy and Wood, 2015) to provide an early warning forecast. This is especially beneficial for more remote areas of the world where there is not a large observation network and where land-atmosphere interactions play a role in drought (e.g. Africa). In addition to drought monitoring, this long-term global coverage dataset of land-atmosphere coupling from satellite remote sensing can also be used to understand the change and strength of land-atmosphere interactions over time and space. This information could be very valuable for model development and calibration that could lead to better predictions.